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(54) **Method of plating steel.**

(57) To form a plating coat on steel works, the works are held in a fluorine- or fluoride-containing gas atmosphere in a heated condition to thereby remove oxidized scales such as SiOx, MnOx and the like on the surface layer of the work and form a fluoride layer to prevent forming oxidized scale newly. The fluoride layer is easily eliminated by the action of flux added to a plating bath or by holding the fluorinated steel works in an atmosphere containing hydrogen prior to dipping in the plating bath to activate the steel surface. The activated steel surface is improved in compatability with the plating bath and the like to realize a good quality plating coat formation.

EP 0 488 497 A2

This invention relates to a method of plating steel.

Hot zinc dipping and hot aluminum dipping are widely used since a plated coat of either has excellent rust preventive properties, and since those methods are inexpensive. Plating techniques such as hot zinc dipping and hot aluminum dipping are conducted by precleaning the steel works to be plated, for example with acid, then heating them at 650 to 800°C in an annealing process in a reducing atmosphere, cooling them to near the temperature of a plating bath and then dipping them in the plating bath to form a plating coat. In such a plating process, in order to obtain a good quality plating coat, not only is sufficient precleaning of the steel articles required, but also it is preferable that oxidized scale such as SiO_x, MnO_x on the steel work surface layer is not formed in the annealing process under the reducing atmosphere. Works now often contain high levels of silicon, since continuous casting material is used and a high strength material is required. The silicon in the steel work changes to an oxidized scale in the annealing process in the reducing atmosphere. This scale is an obstacle to forming a plating coat, causing problems such as uneven plating and bad appearance.

In order to prevent the generation of oxidized scale, it is necessary not to convert Si and the like to oxidized scale in the annealing process in the reducing atmosphere. Generally, however, in a conventional continuous treatment process, a reducing atmosphere is formed of a mixed gas composed of N₂ and H₂, and the above-mentioned steel materials are heated and cooled in this atmosphere. Since formation of an oxide of Si or Mn requires little energy, an oxide scale is readily formed. Therefore, it is impossible to prevent the above oxidation completely even if the reducing property is increased and even if the heating temperature is lowered. For example, in hot zinc dipping, steel material containing not less than 0.5% Si deteriorates in plating quality since the wettability of the plating bath is reduced due to the oxide scale formation. In hot aluminum dipping, the above problem is also caused with steel containing not less than 2% Si.

Accordingly, it has been desired to provide a method of plating steel in which a high quality plating coat is readily formed.

According to the invention there is provided a method of plating steel to form a plating coat on a steel work or article comprising:

exposing the steel work or article to an atmosphere of fluorine- or fluoride-containing gas; and

then forming a plating coat on the fluorided work or article.

In this invention, prior to forming a plating coat

on the steel work or article, they are held in an atmosphere of fluorine- or fluoride-containing gas, preferably in a heated condition, whereby oxidized scale such as SiO_x and -MnO_x on the steel work surface is removed and at the same time a fluoride layer is formed so that the surface of the steel work is covered with the fluoride layer. The fluoride layer generally comprises a thin film of a thickness of about several tens to several thousands Å and is stable at 300°C to 600°C and prevents the new formation of oxidized scale. Since the fluoride layer is more porous than an oxide layer formed at the same temperature and has rich sublimation, it is easily removed by the action of an added flux such as chloride and/or Al in to the plating bath of the next step. As for the removal of the fluorinated layer, steel works with the fluoride layer formed thereon are introduced into an atmosphere of an inert gas containing hydrogen or an atmosphere containing moisture (water) and heated to remove the layer, prior to being dipped in the above-mentioned plating bath. Since the steel surface is activated on removal of the fluoride layer, its conformability with a plating bath and the like is improved to achieve formation of a good quality plating coat.

This invention is described in detail below.

In this invention, steel works are charged into a heating and cooling furnace and held in an atmosphere of fluorine- or fluoride-containing gas in a heated condition, and then a plating coat is formed thereon.

Subjects to be plated are steel works. Steel works includes various steel materials such as carbon steel or stainless steel. The form of the steel works is not limited. They may be in the form of plate or sheet, coil, or screw which is processed. The steel materials used in this invention include not only a single material but also alloys composed of iron as a main component with other metallic materials.

Fluorine- or fluoride-containing gas used for making a fluorine- or fluoride-containing gas atmosphere means a gas in which fluorine-source component is one of or a mixture of NF₃, BF₃, CF₄, HF, SF₆, F₂, CH₂F₂, CH₃F, C₂F₆, WF₆, CHF₃, SiF₄ and the like in an inert gas such as N₂.

Among the fluorine source component mentioned above, NF₃ is the most suited for practical use since it is superior in safety, reactivity, controllability, ease of handling. A mixed gas composed of, for example 1% NF₃ gas + 5% F₂ + 94% N₂ (by weight) is also useful. In such a fluorine- or fluoride-containing gas, the preferred concentration of the fluorine component such as NF₃ and the like is 1 to 15%, more preferably 2 to 7% by weight (weight standard: hereinafter the same) from the view point of efficiency. The at-

mosphere of fluorine- or fluoride-containing gas is formed by filling such a gas or a mixture in a predetermined space.

According to a preferred embodiment of the invention, the steel material is plated, for example, as follows. That is, a little idea is added to a cooling step in a conventional whole plating process. In more detail, the steel material heated to between 650°C and 750°C is cooled then introduced into an atmosphere of fluorine- and fluoride-containing gas and held therein at 300°C and 600°C for one to eight minutes, preferably two or three minutes. By holding the steel in such an atmosphere, oxides such as SiOx, and MnOx on the surface of the steel material are eliminated and a fluoride layer is formed thereon. Then the steel material with the fluoride layer formed on its surface is dipped in a plating bath such as a zinc plating bath or an aluminum plating bath or the like to form a plating coat. In this case, the fluorinated steel works are not dipped in the plating bath directly, but the works may be contacted with a mixed gas composed of hydrogen and nitrogen (H₂; 90 to 10% + N₂; the balance) to remove the fluoride layer, and then dipped in the plating bath. In a series of process, the amount of NF₃ to obtain a good quality plating coat is preferably about 50g to 700g per ton of the steel material.

In the drawings, Fig. 1 shows a cross-sectional view of an example of a treatment furnace used in this invention,

Fig. 2 shows a partially enlarged view of a part A of Figure 1, and

Fig. 3, 4 and 5 show depth-direction elemental analysis curves by SIMS.

EXAMPLE 1(a)

An experimental heat treatment furnace 1 as shown in Fig. 1 was used. In the figure, reference numeral 20 is a furnace body having adiabatic walls, 21 are heaters disposed in the wall of the furnace body 20 and 22 is a slidable door disposed at the bottom of the furnace body 20. The door 22 slides right and left as seen in Fig. 1. At the ceiling of the furnace body 20 is connected a conduit 23 for introducing a gas into the furnace 20. The reference numeral 24 indicates steel articles to be treated. Under the furnace 20 is disposed a zinc pot furnace 25 which is separated by the slidable door 22. In the zinc pot furnace 25, an induction coil 26 is disposed in the surrounding walls as shown in Fig. 2, and liquid zinc at 480°C is filled therein.

In this furnace, a few samples of steel works (cold-rolled steel material: 1% Si, 0.2% Mn) were heated to 750°C in an N₂ atmosphere, then cooled to 350°C, then a fluoride containing gas (N₂ + 5%

NF₃) was blown into the furnace for one minute and held therein for two to five minutes. After that, N₂ gas was blown in, the temperature was raised to 500°C and then one of the samples was taken out of the furnace for elemental analysis. The rest of the samples were transferred into the zinc pot furnace 25 by opening the slidable door 22 and dipped in a zincing bath to coat them with zinc. After plating with zinc, they were taken out of the furnace 25 and at the same time blown with N₂ gas, then cooled and dried, whereby plated samples were produced.

EXAMPLE 1(b)

This was conducted as Example 1(a), except that after supplying the fluoride-containing gas composed of N₂ + 5% NF₃ into the heat treatment furnace and holding the samples for two to five minutes therein, a mixed gas composed of N₂ + 25% H₂ was supplied therein and under the atmosphere the samples were heated to 500°C and held for ten minutes. Then the samples were transferred into the zinc pot furnace 25 to galvanize them. The same plated samples were produced as mentioned above.

EXAMPLE 2

Steel samples were heated to 750°C in an N₂ atmosphere, cooled to 500°C and held in an atmosphere of fluorine- or fluoride-containing gas having the same composition as in Example 1(a). This apart, plated samples were made as in Example 1.

EXAMPLE 3

A mixed gas composed of 1% NF₃ + 5% F₂ + 94% N₂ was used as the fluorine- or fluoride-containing gas. That apart, plated samples were made as in Example 1(a).

COMPARATIVE EXAMPLE

The same samples used in the Example 1 were used and they were heated at 750°C in an N₂ + 50% H₂ atmosphere, then cooled to 500°C and dipped in a zincing bath as in Example 1 without fluorination. This apart, plated samples were obtained in the Example 1.

An elemental analysis of the depth in the surface layer part was conducted by SIMS (secondary ion mass spectrometry) against an unplated sample (what are in a sample immediately before plating) obtained in the Examples 1(a), 2 and the Comparative Example. The results are shown in Figs. 3, 4 and 5. In these Figures, straight line A

shows Fe, straight line B; Si, straight line C; Mn. Fig. 3 corresponds to Example 1(a), Fig. 4 to Example 2 and Fig. 5 to the Comparative Example. That is, "concentration" of Si and/or Mn (Concentrating degree of Si and/or Mn is relatively high.) was not seen in the outside surface layer part in Examples 1 and 2 as is clearly seen in Figs. 3 and 4. On the contrary, in the Comparative Example shown in Fig. 5, oxidation of the outside surface layer occurred to form oxides such as SiOx and MnOx on the surface layer, whereby the concentration of Si and Mn in the surface layer becomes relatively high. We define this condition as "concentration."

A bending part was examined by conducting an adhesion bending test for examining the adhesiveness of the plating coat on each sample produced in the Examples and the Comparative Examples. As a result, blistering of the plating coat was not seen on the bending part in Examples 1(a), 1(b) and 2, while extensive blistering and bad adhesiveness of the plating coat was observed on the bending part of the Comparative Example. The sample obtained from Example 3 showed the same structure and the same plating coat properties as those obtained from Example 1(a).

It is apparent from the results given above that it is possible, by use of the invention, to conduct high quality plating such as a hot zinc dipping of high Si content steel materials which are hard to plate conventionally, and that it is also possible to produce steel sheet or steel plate of high strength. In addition, the use of H₂ gas to provide a reducing atmosphere for annealing may be largely or wholly avoided, giving a saving in cost. In the Examples, an experimental furnace apparatus was used for plating, but it is possible to carry out the invention by utilizing ready-made equipment by modifying cooling step equipment of an actual continuous hot zinc dipping line.

As mentioned above, in methods of plating steel according to the invention, since a plating coat is formed on the steel surface after holding the steel material in an atmosphere of fluorine- or fluoride-containing gas in a heated condition, surface oxide layer is removed and a fluoride layer is formed thereon to cover and protect the surface. The steel material with the fluoride layer formed is dipped in a plating bath directly or introduced in an inert gas atmosphere containing hydrogen and heated to thereby decompose and remove the fluoride layer, and then dipped in the plating bath. In the case of dipping in the plating bath directly, the fluoride layer is decomposed and removed by the action of an added flux such as chloride and Al added to the plating bath. In the case of dipping in the plating bath after introducing the steel work into the hydrogen-containing inert gas atmosphere,

since the fluoride layer is removed prior to dipping in the plating bath, the plating treatment can be done swiftly. In this way the fluoride layer is removed and an activated steel surface is exposed. The plating coat is well-adhered and formed preferably on the activated steel surface to give high quality plating.

Claims

1. A method of plating steel to form a plating coat on a steel work or article comprising:
 - exposing the steel work or article to an atmosphere of fluorine- or fluoride-containing gas; and
 - then forming a plating coat on the fluorided work or article.
2. A method according to claim 1, in which the fluorine- or fluoride-containing gas comprises an inert gas and at least one of NF₃, BF₃, CF₄, HF, SF₆, F₂, CH₂F₂, CH₃F, C₂F₆, WF₆, CHF₃ and SiF₄ together.
3. A method according to claim 1 or 2 in which the fluorine- or fluoride-containing gas comprises from 1% to 15%, preferably from 2% to 7%, by weight of the fluorine-containing component.
4. A method according to any preceding claim in which the fluorine- or fluoride-containing gas is at from 300 °C to 600 °C.
5. A method according to any preceding claim in which the work or article is exposed to the fluorine- or fluoride-containing atmosphere for from 1 minute to 8 minutes, preferably for from 2 minutes to 3 minutes.
6. A method according to any preceding claim further comprising exposing the work or article to a reducing atmosphere after exposure to the fluorine- or fluoride-containing atmosphere and therefore forming the plating coat on the article or work.
7. A method according to any preceding claim in which from 50g to 700g NF₃ is used per ton of steel.

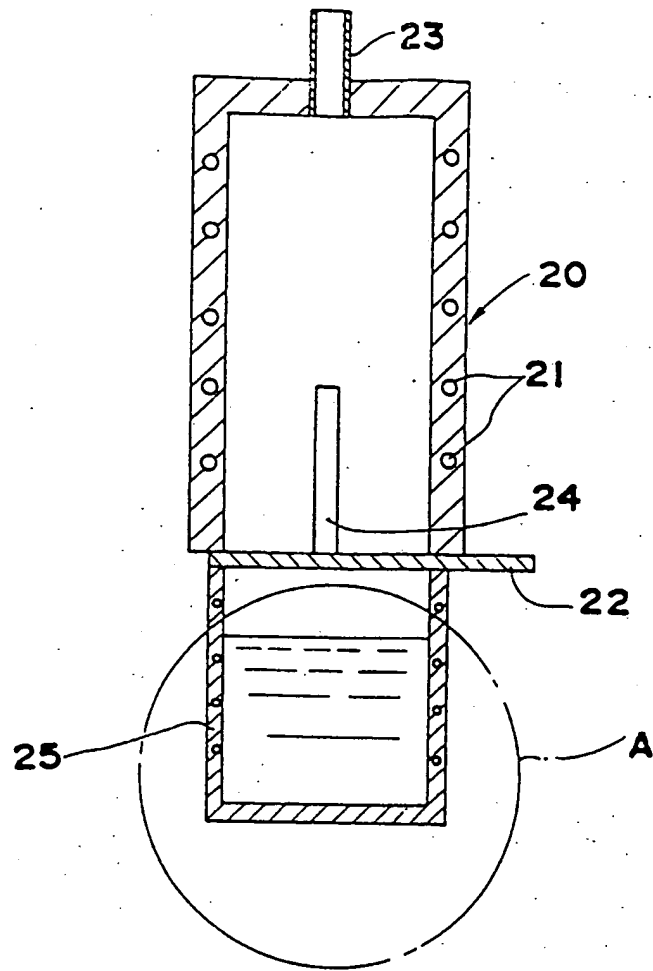


FIG. 1

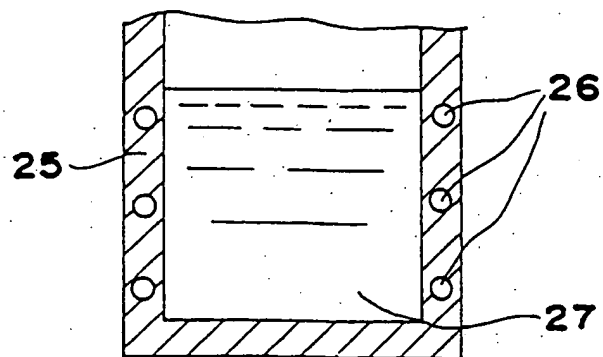


FIG. 2

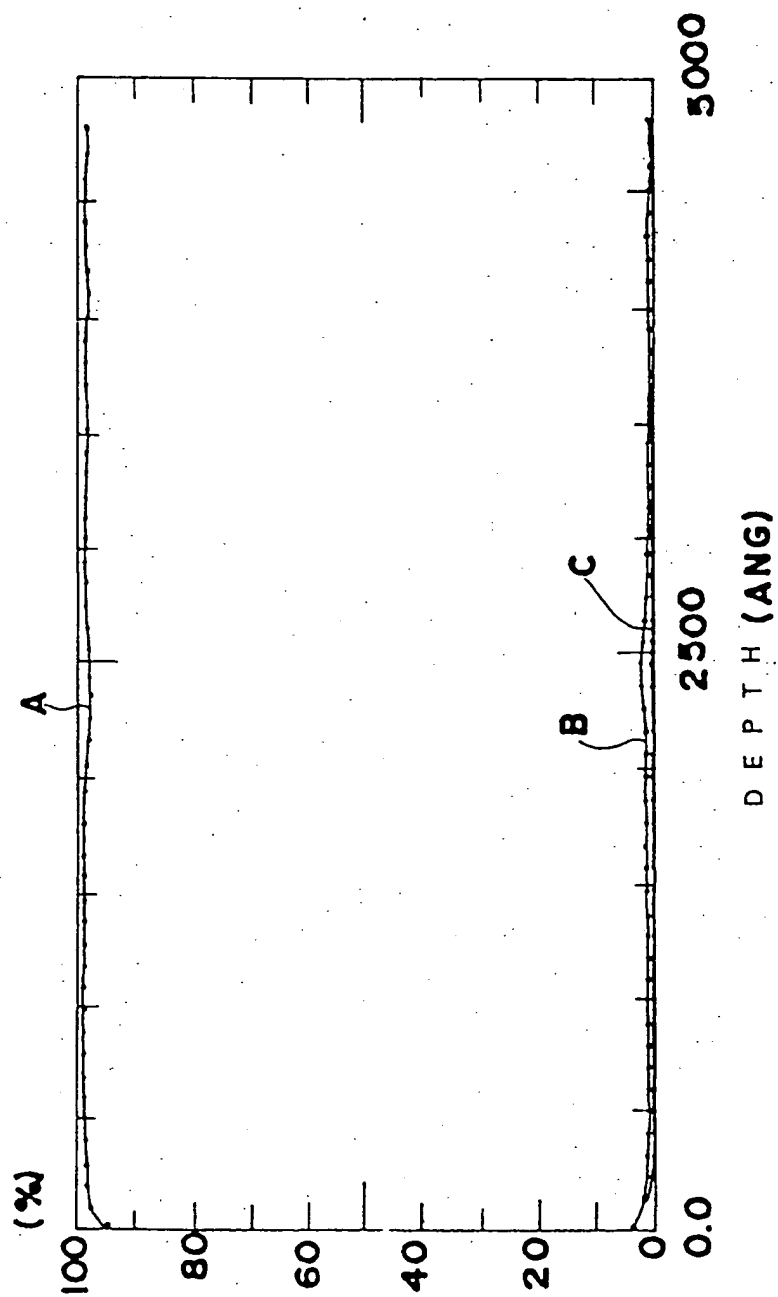


FIG. 3

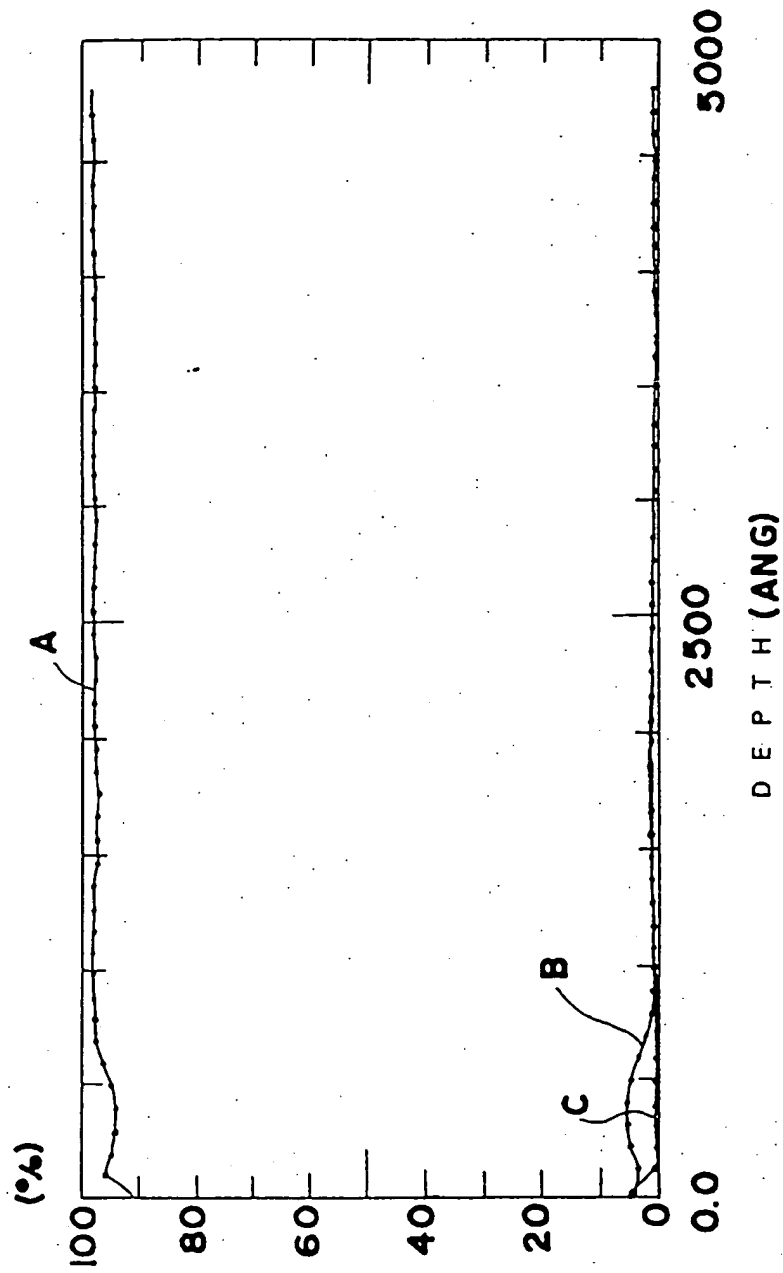


FIG. 4

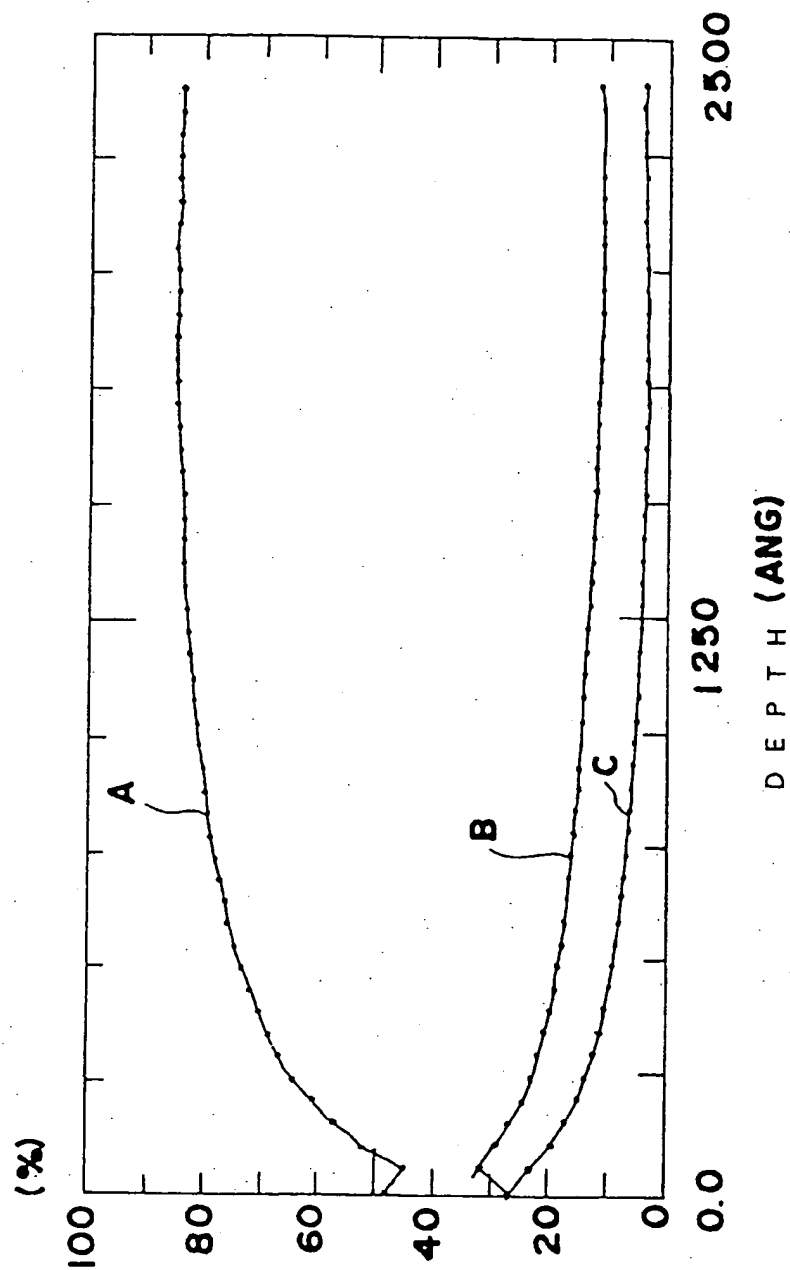


FIG. 5